Proceedings of ICRC 2001: 1 © Copernicus Gesellschaft 2001

ICRC 2001

Status of Project GRAND's Proportional Wire Chamber Array

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Abstract. Project GRAND is an extensive air shower array of proportional wire chambers. It has 64 stations in a 100 m x 100 m area; each station has eight planes of proportional wire chambers with a 50 mm steel absorber plate above the bottom two planes. This arrangement of planes, each 1.25 square meters of area, allow an angular measurement for each track to 0.25° in each of two projections. The steel absorber plate allows a measurement of the identity of each muon track to 96% accuracy. Two data-taking triggers allow data to be simultaneously taken for a) extensive air showers (multiple coincidence station hits) at about 1 Hz and b) single muons (single tracks of identified muons) at 2000 Hz. Eight on-line computers pre-analyze the single track data and store the results on magnetic tape in compacted form with a minimum of computer dead-time. One additional computer reads data from the shower triggers and records this raw data on a separate magnetic tape with no pre-analysis.

1 Introduction

Project GRAND utilizes a rather different technique of studying cosmic ray showers. Instead of the traditional method of measuring the orientation of the shower front by means of timing counters, GRAND uses eight planes of proportional wire chambers stacked vertically on top of each other with a steel plate above the bottom two planes to geometrically measure the angles of the secondary tracks in the shower. The steel absorber plate allows muon tracks to be identified.

By locating four points (three in the case of electron tracks which do not make it through the steel plate) on a track trajectory in the x plane and four in the y plane, the angle of the secondary tracks are measured in these two orthogonal planes yielding its three-dimensional orientation in space. The angle of the primary cosmic ray is obtained by averaging the angles of the many secondary tracks of the associated extensive air shower. In averaging, the accuracy increases for showers with more secondary tracks.

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2 Experimental Array

Each of the 64 stations is composed of four pairs of orthogonal planes. Each plane contains 80 detection wires; the planes are aligned to within $\pm 0.2°$ with the north/south or east/west directions. Adjacent planes are constructed orthogonal to one another to $\pm 0.1°$. Originally the array was designed to study extensive air showers produced by cosmic ray primaries $\geq$ 100 TeV. However, since each secondary track's angle is measured and its identity determined, GRAND obtains large quantities of data on single muon tracks along with the extensive air shower data. The experiment now runs two simultaneous triggers: a) a coincidence trigger of $\geq$3 stations for data on extensive air showers, and b) a single-track trigger which collects all tracks stored in all stations 280 times a second; these tracks are about 75% muon tracks. The former trigger is about $\sim$1 Hz and the latter $\sim$ 2000 Hz. These data are stored independently on two different magnetic tape drives.

2.1 Muon Identification

There is a 50 mm steel plate above the bottom pair of planes; electrons scatter, stop, or shower because of the steel absorber plate but the higher mass muons are relatively unaffected. Because an electron will be misidentified as a muon approximately 4% of the time and a muon misidentified as an electron also 4% of the time, this arrangement allows Project GRAND to differentiate muon tracks with 96% precision while retaining 96% of them. Given the 80 channels of proportional wires in a plane and the vertical separation between the planes, GRAND is able to measure the direction of a muon track to 0.26°, on average, in each of two orthogonal planes. This geometrical arrangement of planes has a projected angle sensitivity cutoff-angle of $63°$ from vertical. The muon threshold energy is 0.1 GeV for vertical tracks, increasing as 1/cosϕ for ϕ inclined from vertical.

2.2 Electronics

The electronics was constructed mostly of CMOS integrated circuit chips made possible because of the low instantaneous rate of cosmic rays. The use of shift register memory with parallel inputs and serial outputs allowed the data to be sent to the central electronics trailer on a single data cable for an entire hut with its 640 bits (eight planes) of data information. The use of CMOS chips allows for low power consumption, a large amount of logic in a single chip, and low cost.

The 640 bits of information from the eight planes of a station are read serially down a single data cable at a rate of 12 MHz. The data from all 64 stations are read in parallel in 70 microsec into the central data acquisition area (a trailer obtained from government surplus). The master computer looks for a new event. When it arrives, it determines if there are $\geq$3 huts in coincidence; if so, the master CPU reads the event into its memory and thence to the shower magnetic tape. If this criteria is not meet , it assigns a slave CPU to read in the data, analyze it for single tracks in a station, and store any muon tracks it finds in its internal buffer memory. The master CPU determines if any slave CPU's buffer memory is full and, if so, writes its entire 900 muon buffer to the single-muon magnetic tape.

As stated above, the single muon data is preanalyzed. This analysis examines each station for a single hit in all eight planes (allowing for two adjacent hits which, for a track passing near the middle between two cells, happens about 10% of the time). Upon finding eight single hits in each of the 8 planes of a hut, it stores the location of each of the wire-hits in buffer memory. When the memory reaches 900 muons, it is then written in a single file to magnetic tape (95% of these data fit a straight track on offline analysis). Eight on-line computer nodes working in sequence minimize the deadtime associated with sorting through the total of 40960 bits of information from the entire field for each event read.

The data is stored on two drives, one for shower data and one for single muon data. The shower data is written directly to tape with no pre-analysis; it is rather sparse in hits and, when written in compression mode, stores several weeks of data on a single tape.

The output of single muon data from all eight CPU-s are written to another tape drive. This drive has a backup tapedrive arranged such that, when full, the computer automatically switches to the second drive (and vice versa). Since each drive holds 2.3 day's data, it is only necessary to replace a tape every two or three days in order to keep the experiment running continuously.

2.3 Gas

The PWCs require a slow flow rate of 80% argon plus 20% carbon dioxide gas mixture to maintain the purity of the gas in the PWCs. The flow is such that one T-cylinder of gas furnishes gas for 512 planes of PWCs for two days. The gas system is so configured that when one tank is emptied, a second backup tank is automatically switched unto the sytem; thus the sequence of two cylinders lasts for four days.

2.4 Acceptance

Since Project GRAND is not sensitive to the whole sky (its cutoff projected angle is 63° from zenith); like other ground-based detectors, it is more sensitive to cosmic rays coming from near its zenith. GRAND's acceptance, $Accept$, depends on the track angle given by:

$$Accept = [1 - 0.537 \tan\phi_x][1 - 0.537 \tan\phi_y] \cos^3\phi \quad (1)$$

where the angle ϕ is the muon's angle from the vertical or zenith direction, ϕ_x is the projection of ϕ upon the xz-plane and ϕ_y is the yz-projection. It combines two geometrical factors, a $cos\phi$ factor for the projection of the muons unto the zenith direction, and $\cos^2\phi$ describes muon absorption in the atmosphere due to the increased path length in air for muons inclined from the vertical. The geometrical factor in equation one arises from the arrangement of several horizontal proportional wire planes placed above each other together with the demand that a track traverse both the top and bottom planes. Each PWC plane has 1.25 m^2 of active area.

3 The Proportional Wire Chambers

Mass production of the proportional wire chambers allows them to be built with high precision, uniformity of characteristics, and low cost per unit. In studying cosmic rays it is important to have a large detector area (consistent with available resources); thus cost is important. The original goal was to build these detectors at 0.1 the cost of prior high energy physics experiments. This goal was met in both the chamber and in the associated electronics. Examples of cost savings in the proportional wire chamber construction are the use of glass instead of a epoxy-glass composite and the elimination of sockets for the attachment of the electronics boards.

There are eight planes of proportional wire chambers per station (hut) arranged vertically above each other with 100 mm separation between the planes of a given projection. They are arranged with four in the x-plane (wires running NS) and four in the y-plane (wires running EW). A 50 mm steel plate is located above the bottom two planes. There are 80 cells in each plane (each cell is two paralleled wires). The cells are 14 mm in width with a $\pm$10 mm separation from the high voltage planes. The planes have a total detection area of 1.25 m^2. Four high voltage supplies each furnish a quarter of the high voltage and run the 256 proportional wire planes with a total of 20 milliamps of current. Isolation resistors are used for each hut and each PWC within the hut so that if a wire breaks in a plane and shorts that chamber out, only that hut becomes dead and the rest of the array operates normally. If there are two shorted PWCs in a single quarter at the same time, then enough current is drawn from the power supply for that quarter that it will trip off; this will cause one quarter of the array to become dead, again allowing the remaining 3/4 of the array to operate normally. Because of the uniformity in

characteristics of the planes, each quarter of the experiment is run with all of the PWC planes at the same high voltage; thus no voltage divider boxes are used.

The precision of the dimensional tolerences which were achieved by mass production construction techniques allows stable PWC operation over long periods of time with minimal attention. The high voltage, AC power, gas, clock and data co-ax cables all run underground. Minimal problems have been encountered with some animals needing to be trapped and transported to a distant place to keep them from eating the outer covering of the underground co-ax (you wouldn't think the co-ax to be either that accessible or that tasty).

Each hut enclosure of a detector station has a dehumidifier and a heater. The heater keeps the temperature above 10° C; below this temperature, differential contraction of the signal wires and the PWC glass can break the wires. Dehumidifiers are necessary because the top and bottom plates of a PWCs are a styrofoam-aluminum composite; when the relative humidity rises above ∼50%, water vapor is absorbed into the styrofoam causing partial conductivity and drawing added high voltage current.

4 Summary

GRAND was economical to construct, requires little manpower to operate, and the data is quite easy to analyze. Precision alignment of the PWCs was relatively easy and is absolutely maintained with no further work or adjustments. The PWC detectors are reliable and require little maintainence. The mean-time-to-failure for these proportional plane detectors is ∼1000 years; further improvement could be made easily. The average angular precision for a single muon track is $0.75°$ (projected; 3° for its primary) and for a shower primary is $\sim 0.25°$ (depending on the number of the shower tracks). For each track, in addition to its angular measurement, it is identified as muon (or electron); the muon tracks are better correlated with the primary.

Many references associated with GRAND are contained in Poirier (1999). A more complete and up-to-date list is available on GRAND's Website (2001). The numerical references to papers appearing on the Los Alamos Web Cite are listed in Los Alamos Preprints (2001,00).

Acknowledgements. Thanks are extended to those participating in GRAND's construction, operation, and analyses. GRAND is funded through the University of Notre Dame and private donations.

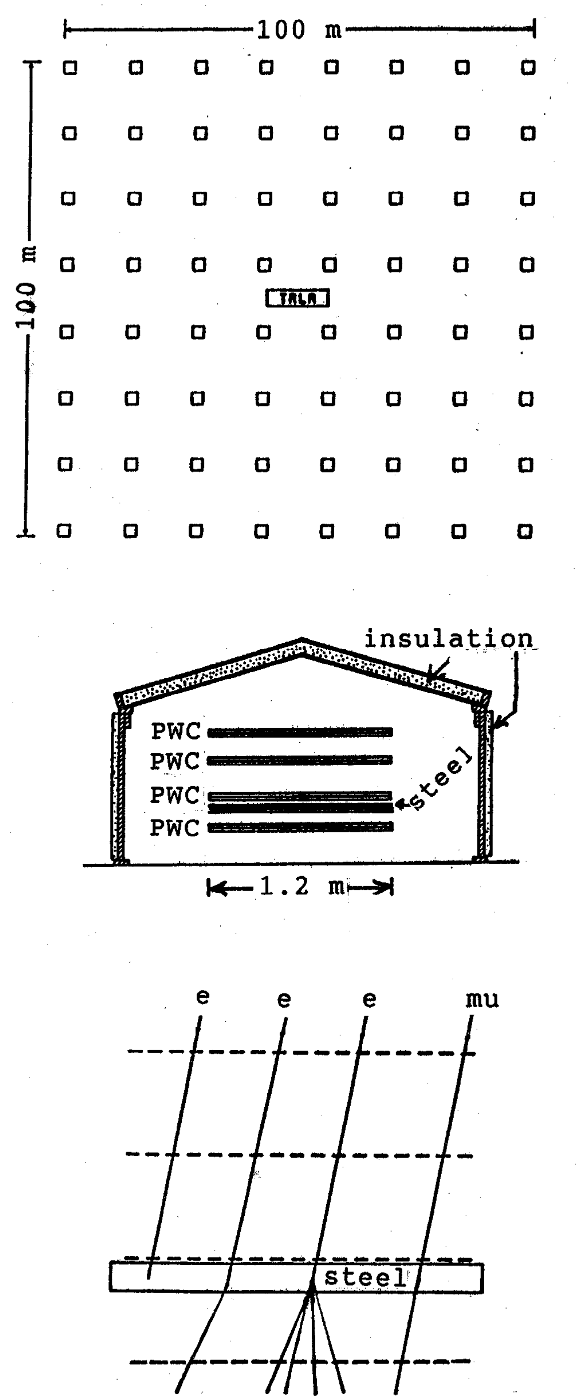

Fig. 1. Top: 100 m x 100 m field of 64 stations and the central electronics trailer. Mid: Vertical cross section of a detector hut; "PWC" denotes two orthogonal proportional planes. Bottom: Schematic of a muon track and three possibilities for electron tracks.

References

GRAND's World Wide Website: http://www.nd.edu/∼grand

Los Alomas Preprint Website http://xxx.lanl.gov astro-ph/**01**03030, **00**08405, 6197, 5415, 5180, 5089, 4398, 4396, 4394, 4379.

Poirier, J., Carpenter, J., Desch, Gress, J., S., Lin, Lu, Y., and Roesch, A., Proceedings of the 26th International Cosmic Ray Conference **5**, 304, 1999.